Energy generation in stars

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Abstract

It is a current opinion that thermonuclear fusion is the main source of the star activity. It is shown below that this source is not unique. There is another electrostatic mechanism of the energy generation which accompanies thermonuclear fusion. Probably, this approach can solve the solar neutrino problem.

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The basic source of energy in stars is the nuclear energy. At high temperature inside a star there are conditions for the thermonuclear fusion. More heavy nuclei have greater bonding energy and greater mass defect. The energy related to this mass defect becomes free at fusion of heavy nuclei and it is used up for a heating of a star and a radiation. This is generally known.

The thermonuclear fusion can be considered as a process of a growing of the averaged mass number A and the averaged charge Z of nuclei in plasma.

The nuclear mass table data show that the bonding energy which becomes free at thermonuclear fusion depend linearly on the averaged charge of nuclei

$$E_m \approx -3 \cdot 10^{-5} Z \ erg \tag{1}$$

But, at consideration of the thermonuclear fusion as an unique process of the energy generation in stars, one looses sight of the fact that there is other additional parallel mechanism of the energy generation - a decrease in the gravitational energy of a star, which is caused by of decrease in the electrostatic energy of plasma and is a result of nuclear charge build-up.

According to the virial theorem [1],[2] the full energy of plasma is equal to the half of its potential energy. The potential energy of plasma inside a star [3],[4] related to one nucleus is

$$E_z = \frac{U}{N_\star} = -\frac{GM_\star^2}{2R_\star N_\star} \tag{2}$$

According to [3], the steady-state value of the star mass is

$$M_\star = 1.5^6 \sqrt{\frac{10}{\pi^3}} \left(\frac{\hbar c}{G m_p^2}\right)^{3/2} \frac{m_p}{(A/Z)^2} \approx$$
$$\approx 6.47 \left(\frac{Z}{A}\right)^2 M_{Ch} \approx 12 \left(\frac{Z}{A}\right)^2 M_\odot \tag{3}$$

and the equilibrium radius

$$R_\star = \frac{3^3}{2^4} \left(\frac{10}{\pi}\right)^{1/6} \frac{e a_0}{G^{1/2} m_p \alpha^{1/2}} \frac{1}{AZ} \approx$$
$$\approx 1.6 \frac{R_\odot}{AZ}, \tag{4}$$

where $M_{Ch} = \left(\frac{\hbar c}{G m_p^2}\right)^{3/2} m_p = 3.42 \cdot 10^{33} g$ is the Chandrasechar's mass, $M_\odot$ and $R_\odot$ are the mass and the radius of the Sun, m_p is the proton mass, G is the gravitational constant, α is the fine structure constant, a_0 is the Bohr radius.

As the equilibrium number of nuclei inside a star is

$$N_\star = M_\star / A \; m_p, \tag{5}$$

with account of Eq.(3) and Eq.(4),

$$E_z \approx -0.8 \left(\frac{\hbar c}{a_0}\right) Z^3 \approx -5 \cdot 10^{-9} \; Z^3 \; erg. \tag{6}$$

Obviously, that the heavy nuclei fusion is really accompanied by a decreasing of electrostatic energy of plasma.

This energy, like the fusion energy, causes a calorification of a star and can be radiated. This energy is related to the process of fusion but it is of

Figure 1: The plasma energy (in Mev) vs an averaged charge of nuclei.

quite a different nature - this is the gravitational energy which is caused by a changing of the electrostatic energy of plasma.

The dependencies of the transmutation energy and the electrostatic energy of plasma on the averaged nuclear charge Z are shown in Fig.1.

The luminosity of a star depends on the energy generation velocity inside it:

$$\frac{dE}{dt} = \frac{dE_m}{dt} + \frac{dE_Z}{dt} = -(3 \cdot 10^{-5} + 1.5 \cdot 10^{-8} Z^2) \frac{dZ}{dt} \quad \frac{erg}{s}. \tag{7}$$

The dependencies of energy generation velocities on Z are shown in Fig.2.

Essentially, the full radiation from the surface of a star depends on both - the fusion energy and the decrease in a plasma electrostatic energy. Simulta-

Figure 2: Velocity of energy generation (in $Mev \cdot dZ/dt$) inside a star.

neously, neutrinos are generated by fusion processes only. It is known, that the neutrino flux (with account of all fusion processes) is approximately two times less than the value which can be obtain on the basis of full radiancy of the Sun.

It is possible to conclude from Fig.2, that an averaged charge of nuclei of the plasma core in this case is close to $Z \approx 45$.

References

[1] Landau L.D. and Lifshits E.M. - Statistical Physics,1980, vol.1,3rd edition,Oxford:Pergamon.

[2] Vasiliev B.V. and Luboshits V.L. -Physics-Uspekhi,1994,v.37,pp.345-351.

[3] Vasiliev B.V. - Nuovo Cimento B, 2001, v.116, pp.617.

[4] Vasiliev B.V. - The Physical Approach to Stellar Classification, 2000, Grant Publisher,Moscow.